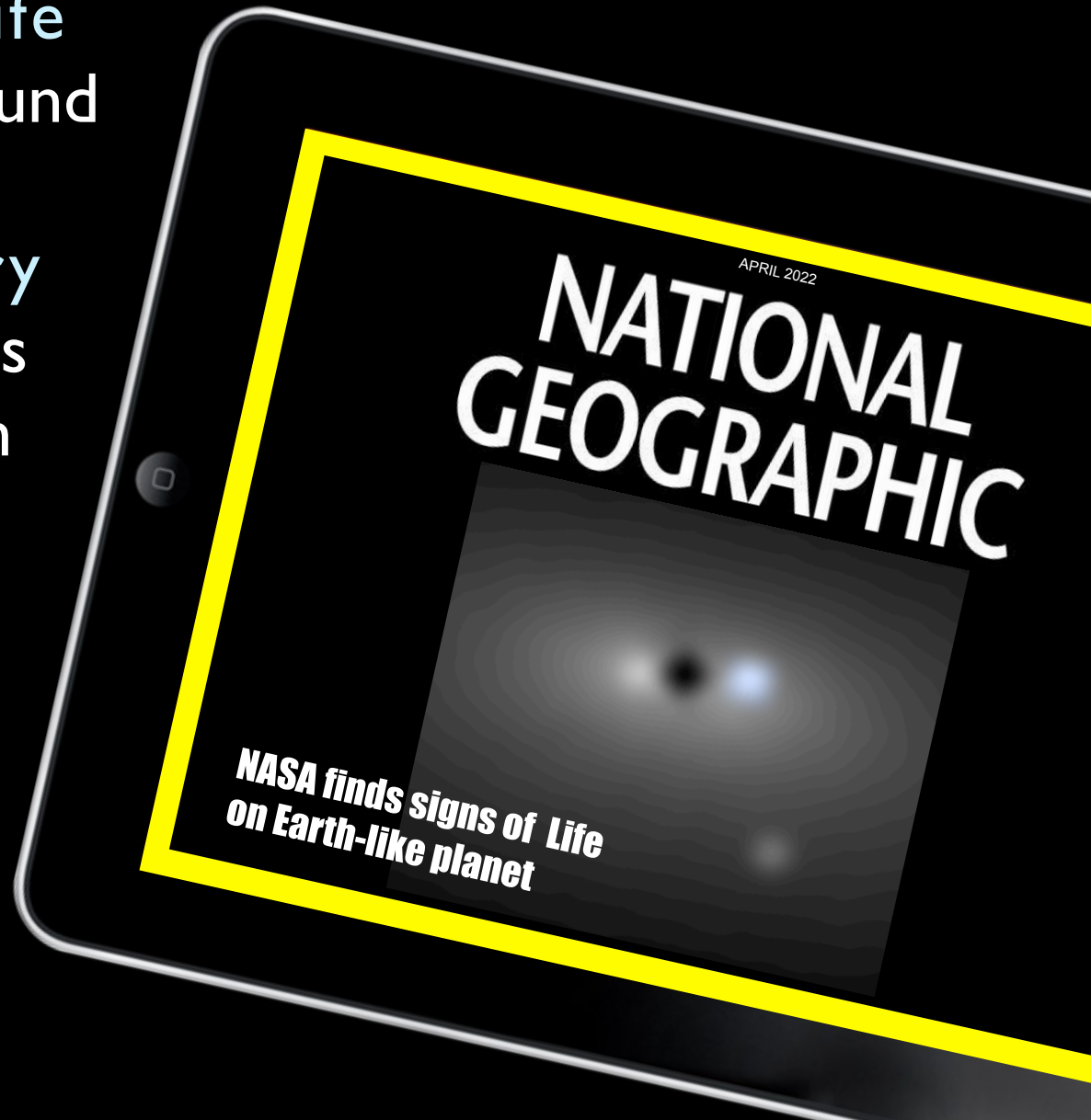


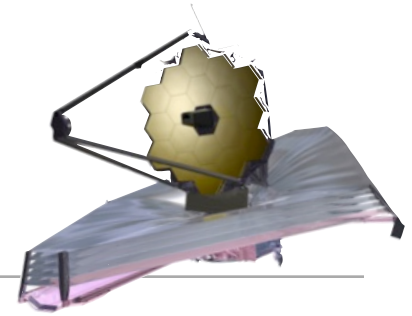
“The discovery of extra-terrestrial life would have as profound an impact on the twenty-first century as Neil Armstrong's Moon walk had on the twentieth.”



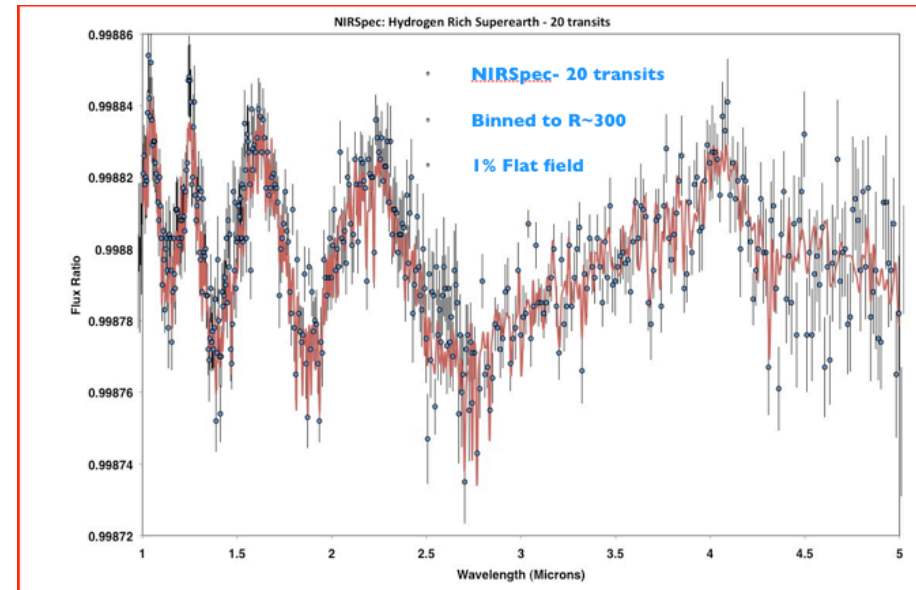
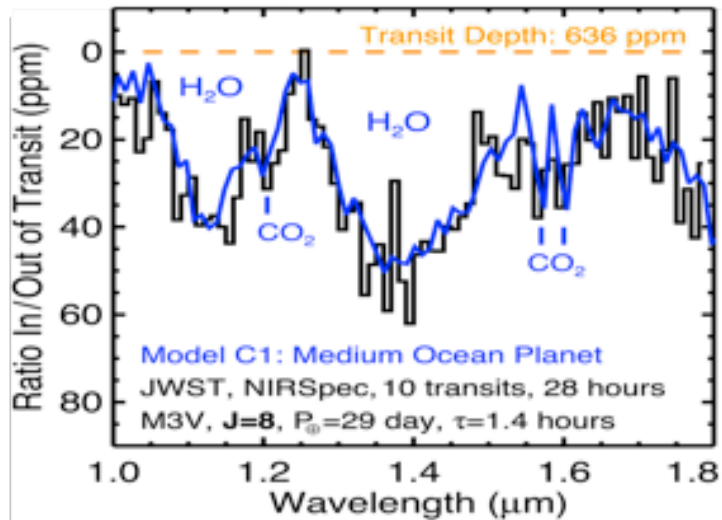
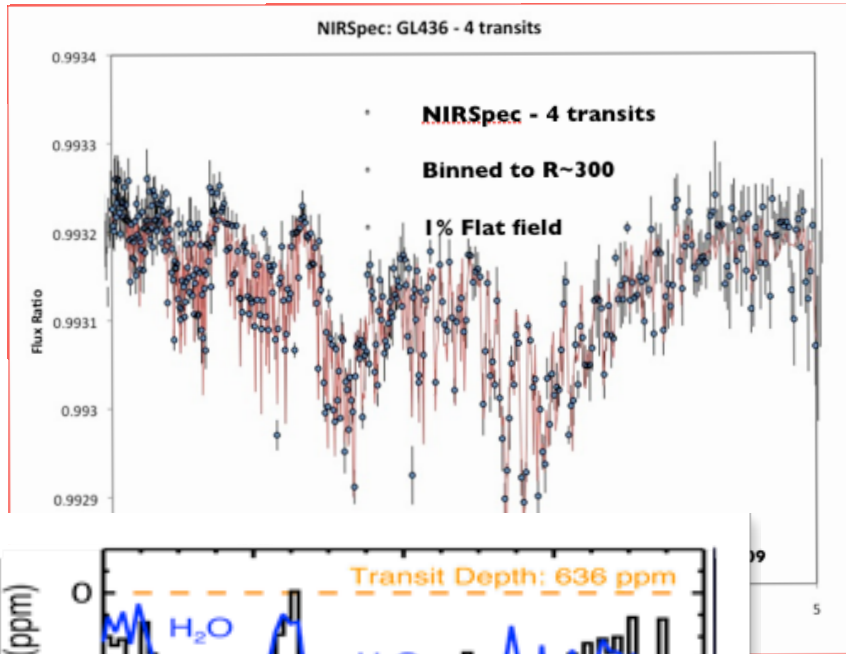
A deep-field photograph of a starry sky, showing a vast number of stars of various colors (yellow, orange, blue, white) against a black background. Several stars are highlighted with green circles, indicating specific points of interest. The text "100 billion planetary systems within our Galaxy" is overlaid in the center.

100 billion planetary systems within our Galaxy

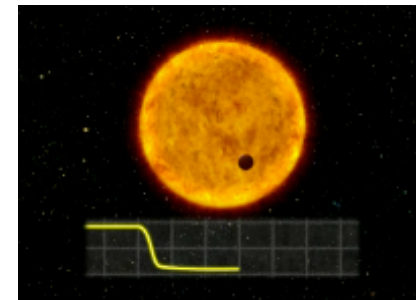
# With JWST we can get close



## extra-solar Uranus - Neptune (Clampin & Lindler)



## Probing the atmospheres of super-earths may be possible (Valenti et al)



# Kepler 22b: a super-Earth

Kepler-22 System

Solar System

Habitable Zone



Kepler-22b

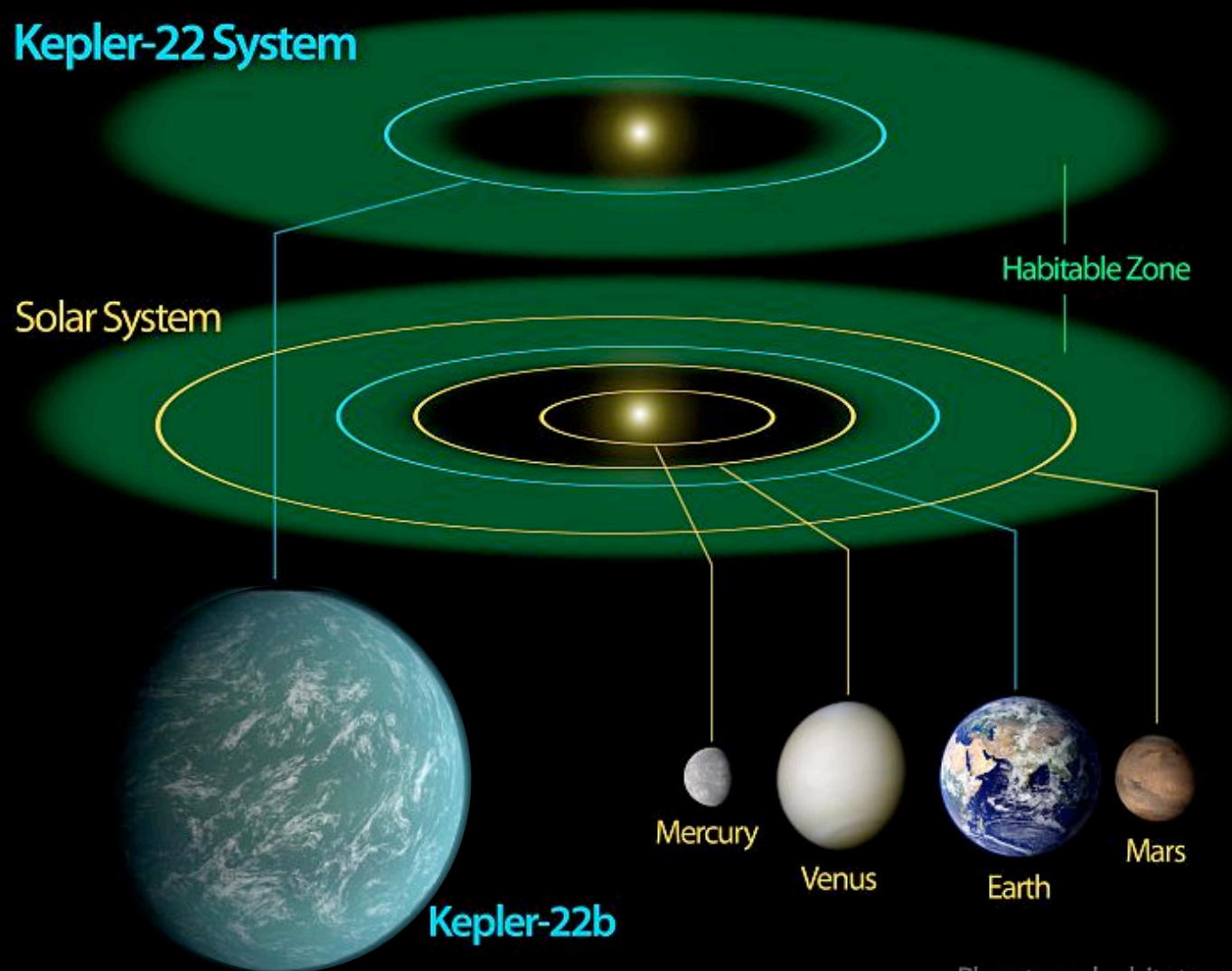
Mercury

Venus

Earth

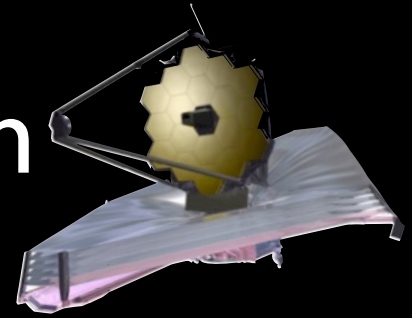
Mars

Planets and orbits to scale





# Kepler 22b: a super-Earth



JWST can observe one transit per year  
the star should be observable up to 4 times/year

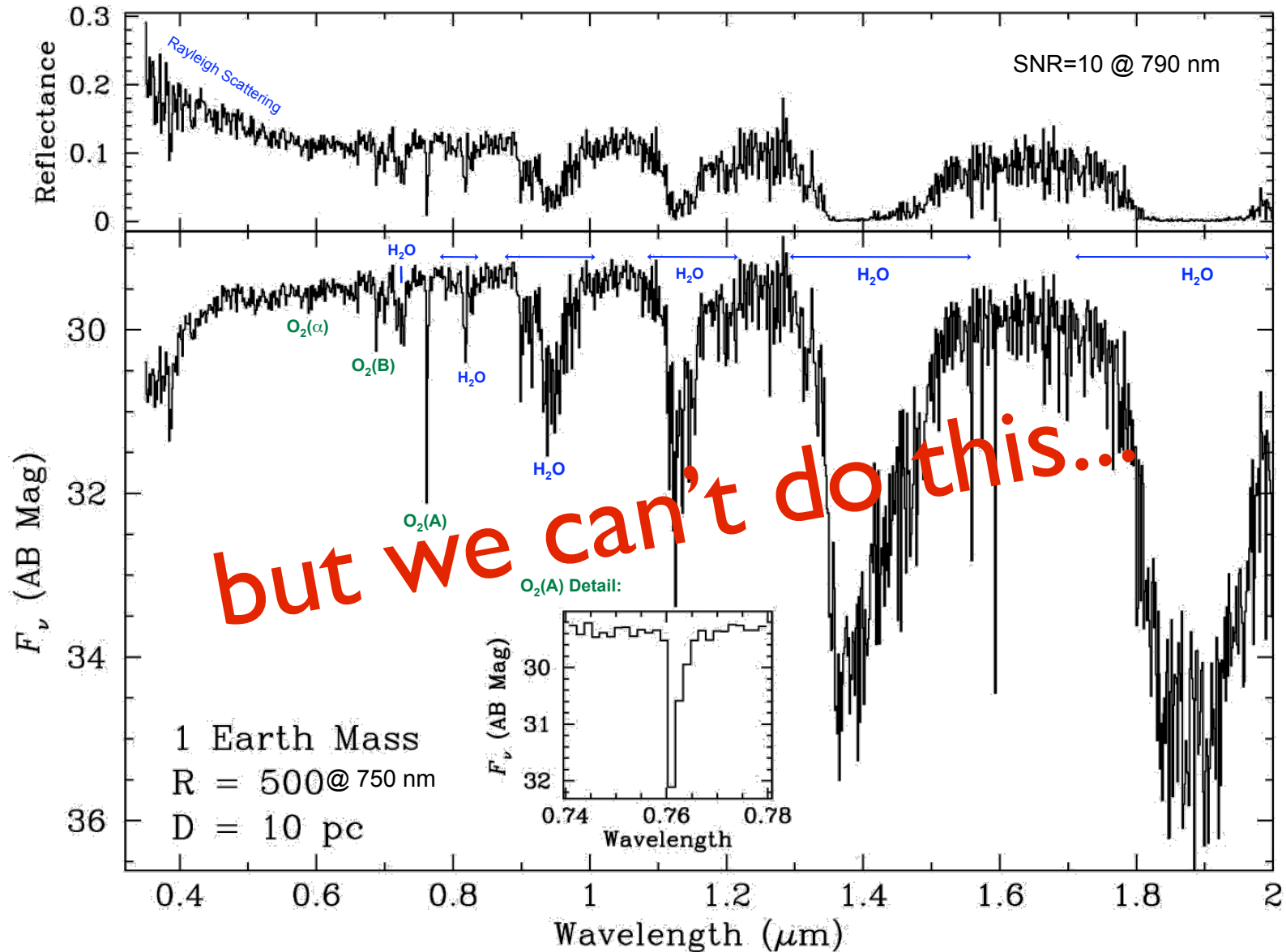
is there water on this world?

JWST can observe 1 transit per year [period of planet]  
Given the ecliptic latitude and orbital period, the star should  
be observable 1-4 times in the first 5 years after JWST launch - a “JWST MCTP”

# Spectrum of 1 Earth-mass Terrestrial Exoplanet at 10 pc R= 500

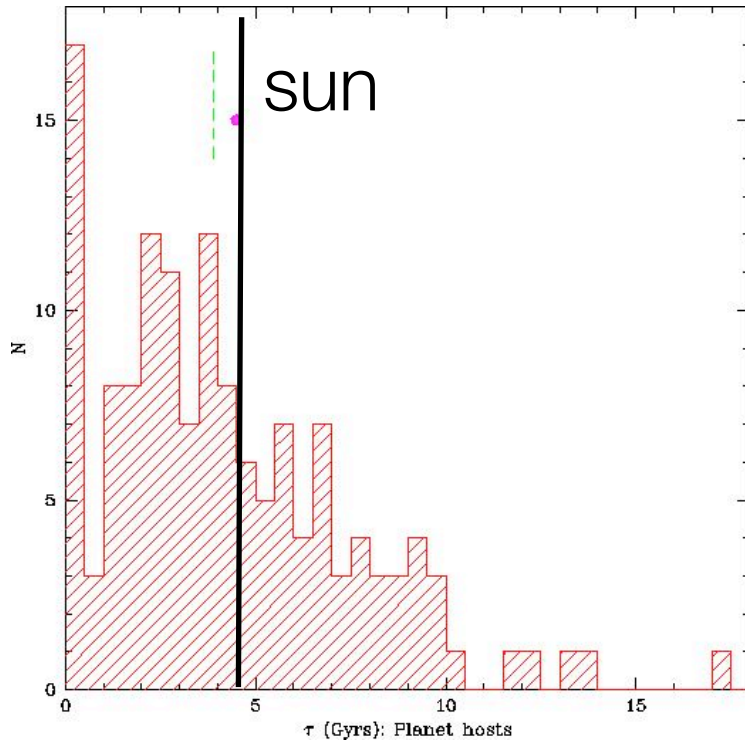
Exposure: 393 ksec on 8-m  
28 ksec on 16-m

Reflectance  $\propto (\text{Planet Mass})^{2/3}$   
5 Earth-mass: 54 ksec on 8-m

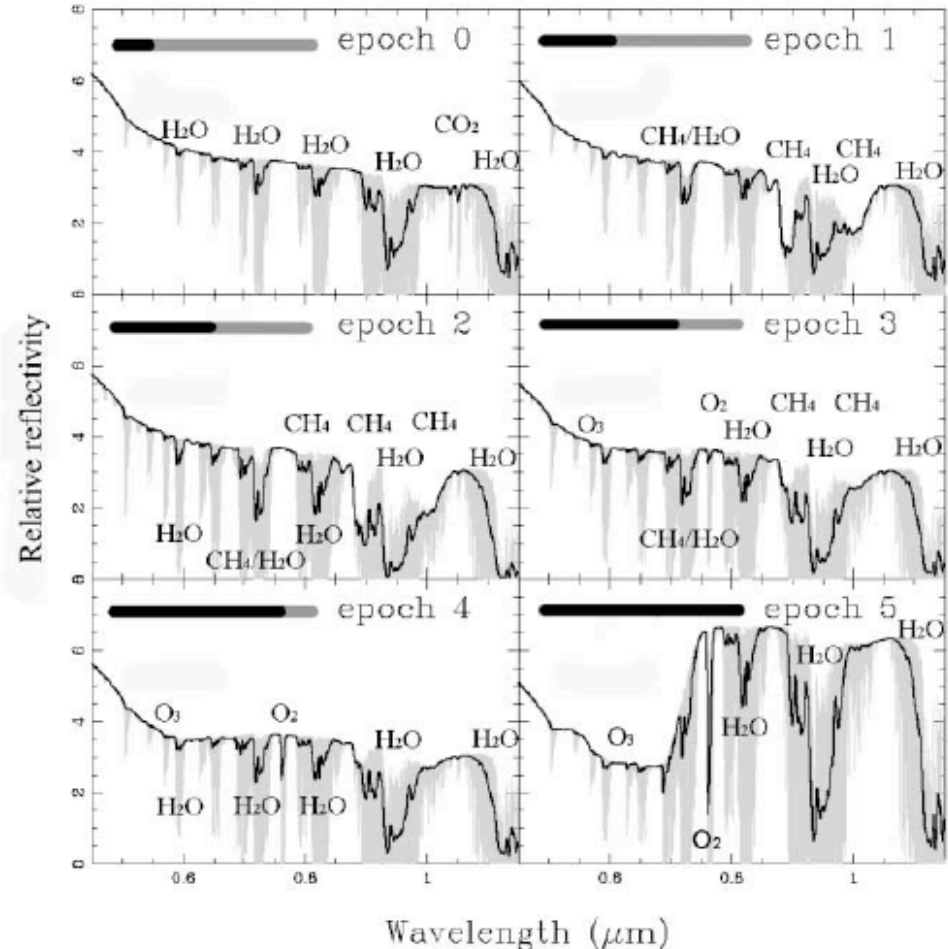


Our other problem: we will not be looking at Earth..

*we need spectra of  $\text{Mag}_{AB}$  30 - 32 objects*

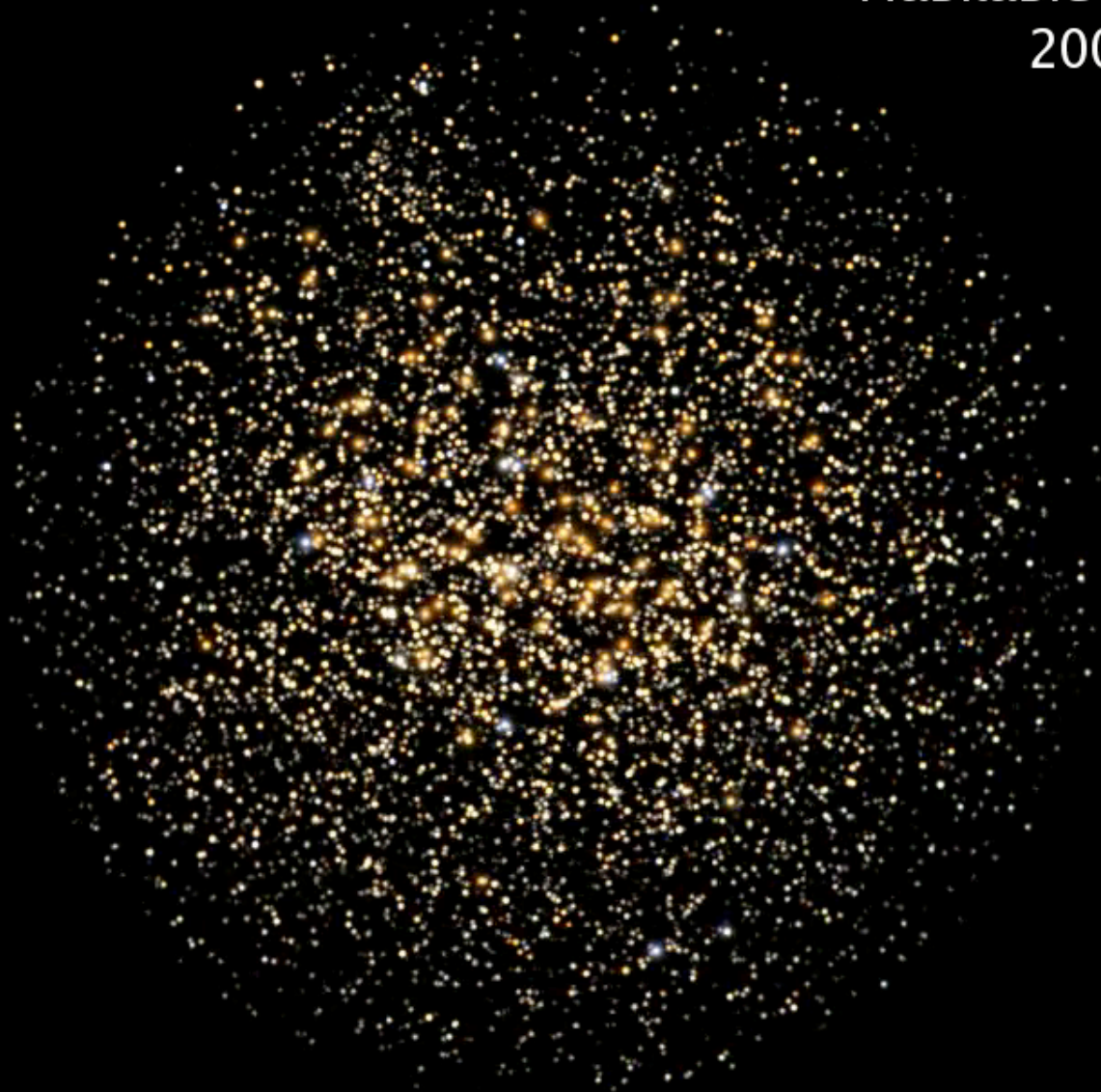


Determination of ages of all stars that  
have planets within 40 pc (130 lyrs)  
median age of distribution  $\sim 3.7$  Gyrs



Courtesy Neill Reid

Habitable Stars within  
200 light-years



~ 4 Meter Mirror  
Space Telescope



10's of candidates

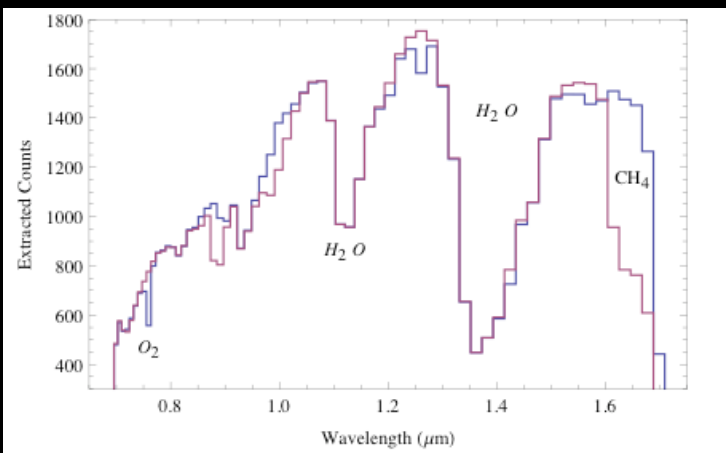
## Shading a New Telescope

Indeed, some astronomers have proposed building such a starshade for the **James Webb Space Telescope**, Hubble's successor, which is scheduled to be launched by NASA later this decade.

“It could potentially not only image an Earth-like planet, but provide some information about its atmosphere and surface,” said David Spergel, an astrophysicist from Princeton.

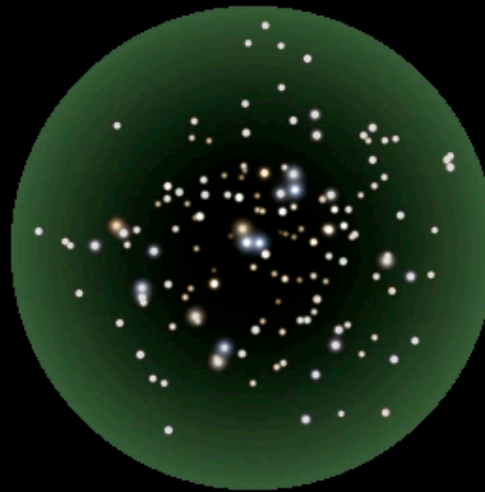
NY Times, 30 January 2011

~ 4 Meter Mirror  
Space Telescope



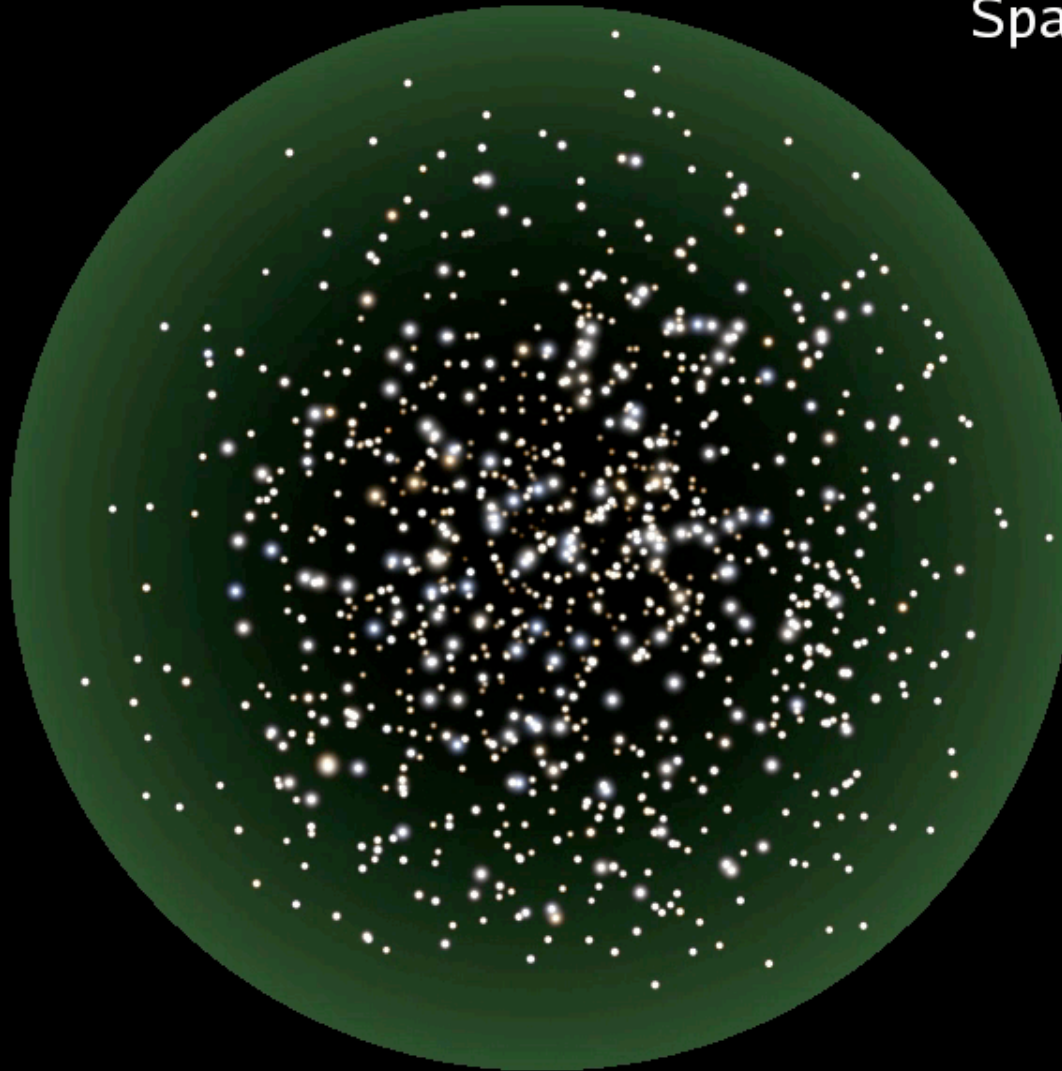
10's of candidates

# 8 Meter Mirror Space Telescope

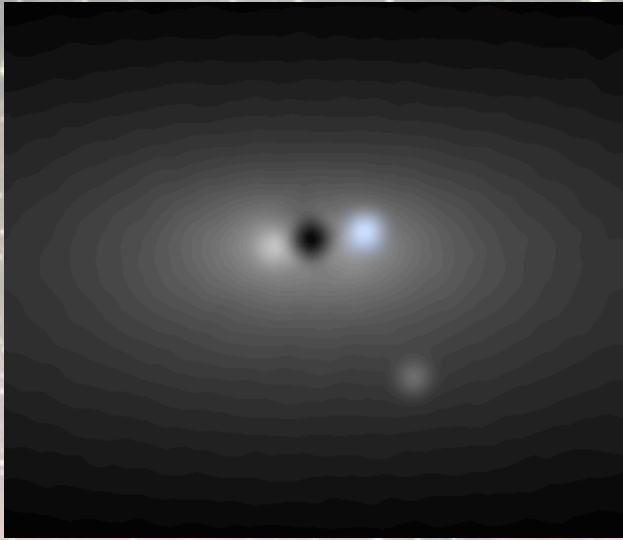


100's of candidates

# 16 Meter Mirror Space Telescope



1000's of candidates

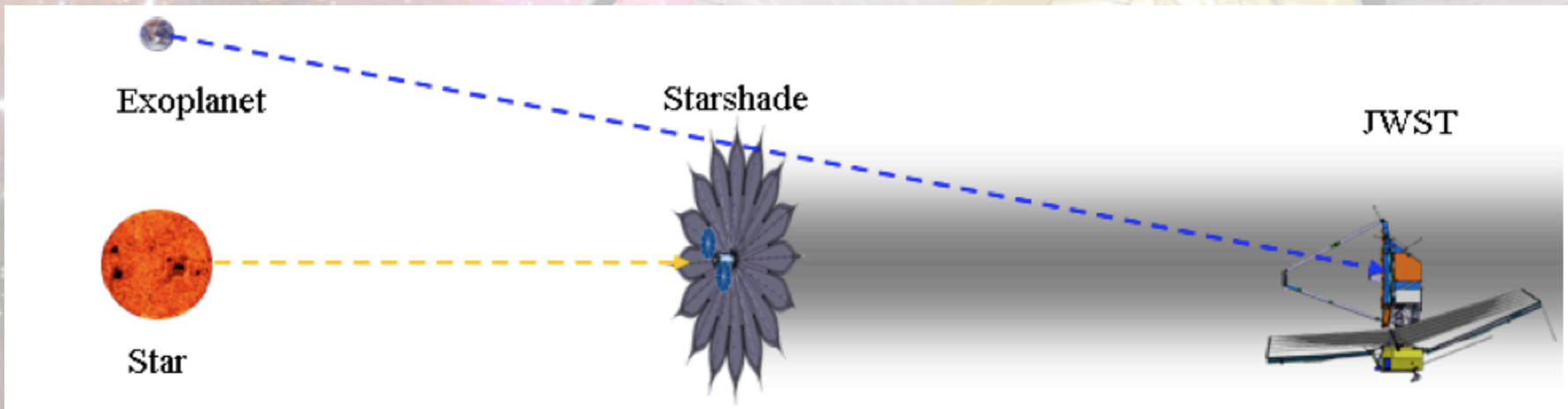


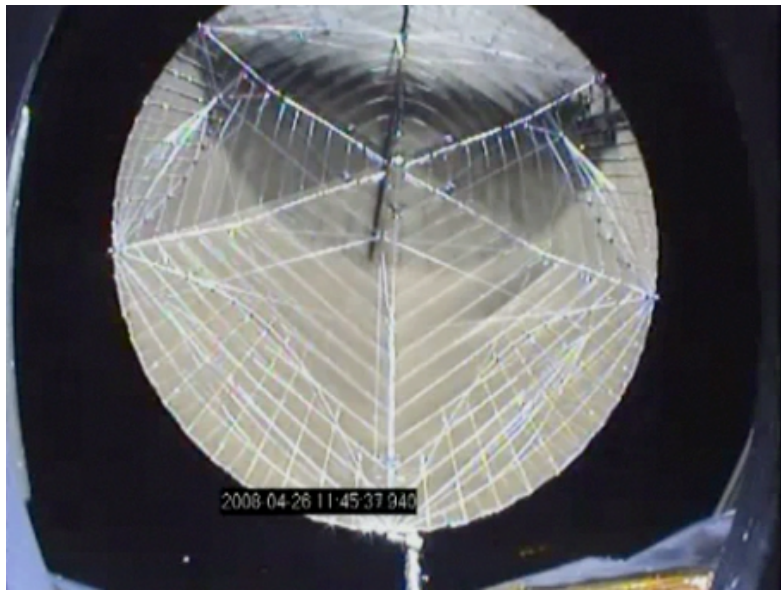
# JWST = TPF-C?

- ▶ **20 - 30 nearby extrasolar systems can be observed and mapped**
- ▶ **5 Earth-size planets could be detected and characterized with low-resolution spectroscopy,**
- ▶ **If  $\eta_{\text{earth}}=0.3$**

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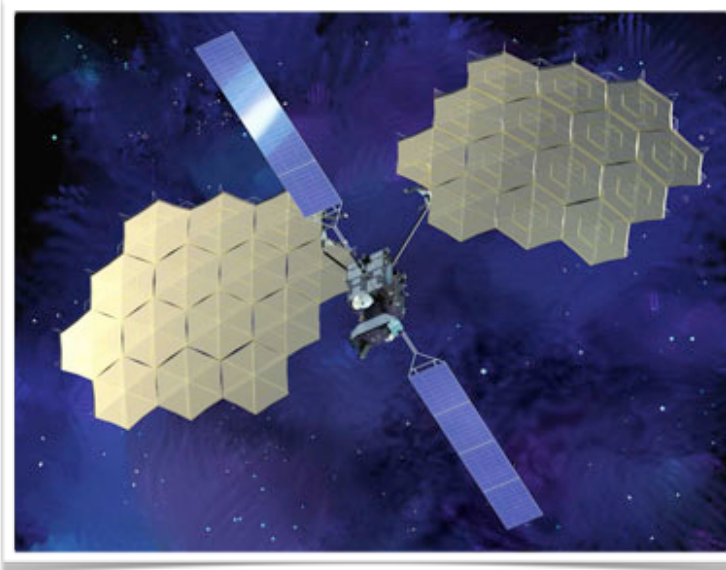
Solar system imaged with JWST and 50m Starshade at 10 pc (courtesy Web Cash)



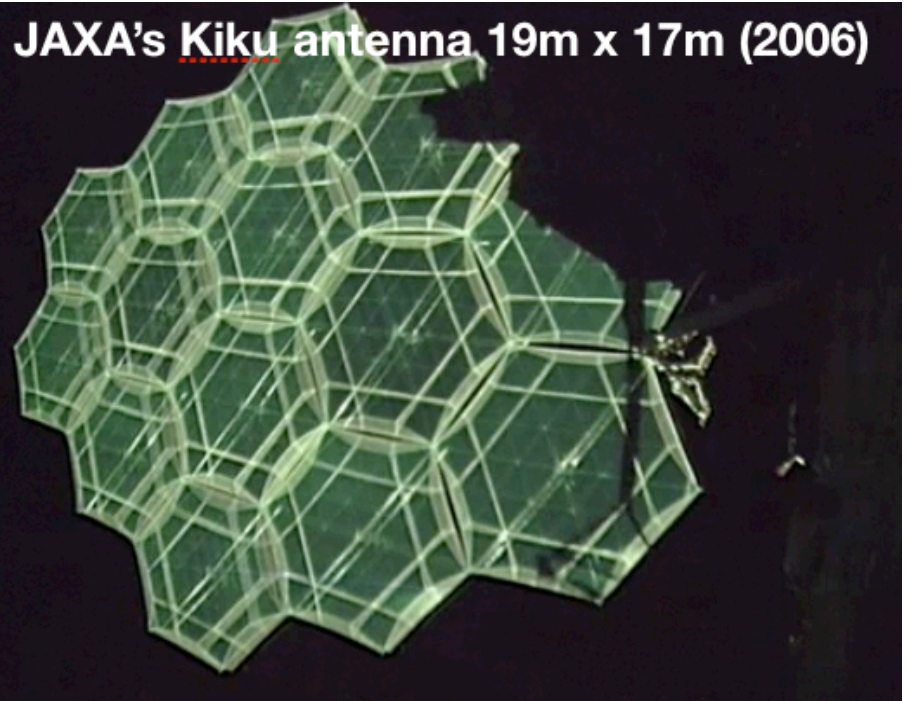


In space ICO-G1 12 meter antenna deployment (2008)

Considerable space technology investment is going into **large** deployable structures



JAXA's Kiku antenna 19m x 17m (2006)



# Petal Tolerances for a 60m - 70m JWST Starshade and State of Art

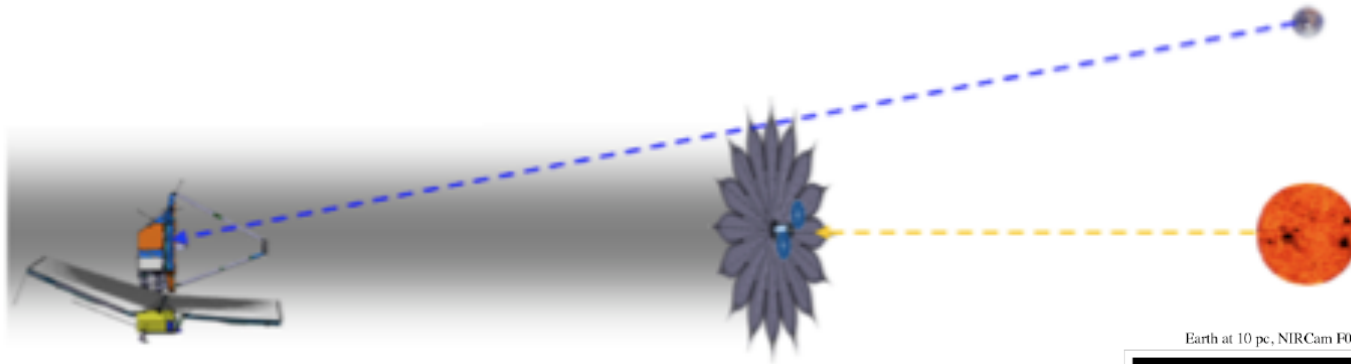
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Petal Tolerances	Required Value	State of Art	Heritage Missions	Materials
Hinge position on perimeter truss	$\pm 1 \text{ mm}$ (1/15,000)	$< 1 \text{ mm}$ (1/30,000)	NGAS AstroMesh reflectors on Thuraya, Inmarsat IV, MBSat	Graphite composites and Kevlar
Out of plane bending, projected to tip	$\pm 10 \text{ cm}$	$\ll 1 \text{ cm}$	Above plus all Springback and Wrap-rib antennas: TDRS H-L, MSAT, DirecTV, ATS-6	Graphite composites
In plane bending, projected to tip	$\pm 5 \text{ cm}$			
Edge shape error	$\pm 120 \mu\text{m}$ (1/17000)	$< 1/30,000$	Springback antennas on TDRS H-L	

Thomson, Lisman, Spergel, Kasdin et al. SPIE poster 2010

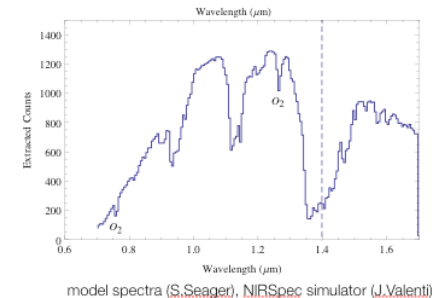
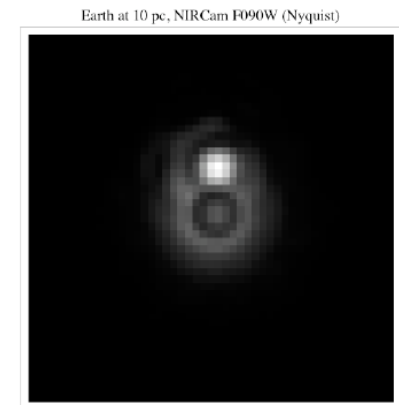


# Search for life - possible in 10 years



JWST + 9% observing time + \$0.7B =

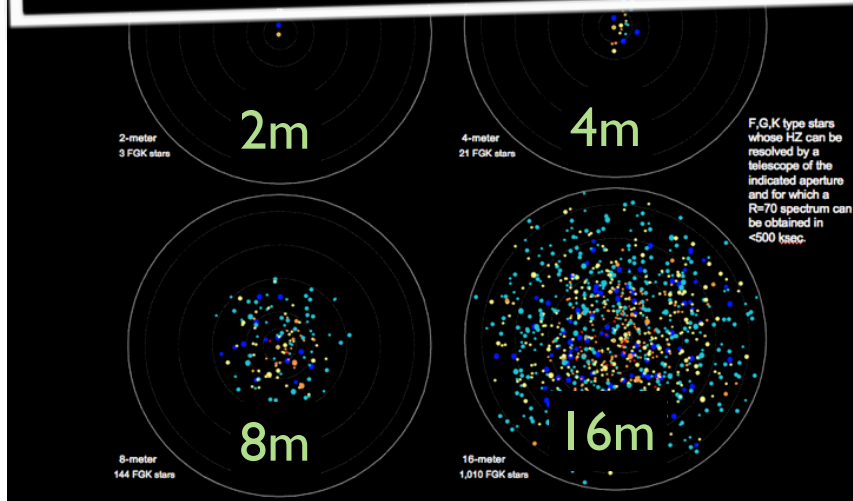
[1 Kepler]



# Astrophysics we can't do today, nor will we be able to do in the JWST era

What are the conditions for planet formation and the emergence of life?

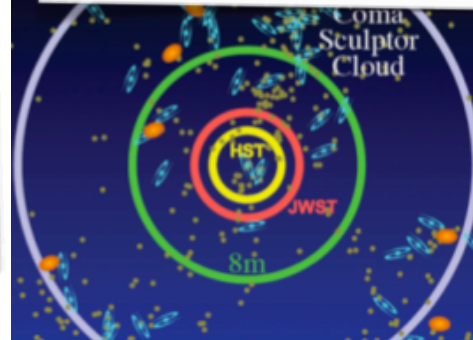
Search for planets around stars other than the Sun, looking for biomarkers in their atmospheres and image them



Number of observable candidate stars in our solar neighborhood as a function of **telescope diameter**

If:  $\eta_{\text{Earth}} \times f_B \sim \text{Kepler}$  then  $D_{\text{Tel}} \sim 4m$   
 $\eta_{\text{Earth}} \times f_B < 1$  then  $D_{\text{Tel}} \sim 8m$   
 $\eta_{\text{Earth}} \times f_B \ll 1$  then  $D_{\text{Tel}} \sim 16m$

How did the Universe originate and what is it made of?



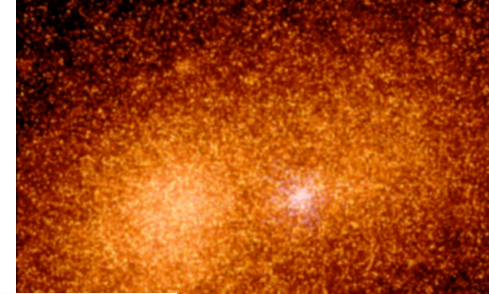
Galactic Neighborhood:

What is the fossil record of galaxy assembly from the first stars to the present?

M31 core as seen with HST



As seen with 10-m in space



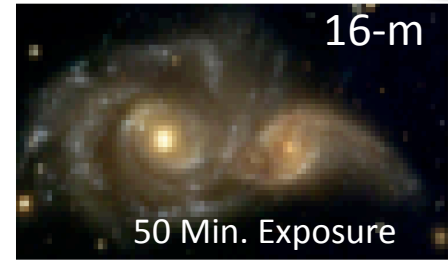
Galaxies Across Cosmic Time:

How do Baryons cycle in and out of galaxies, and what do they do while they are there?

Find the first gravitationally-bound structures - and trace their evolution to the current epoch



10 Day Exposure



50 Min. Exposure



*"for their contributions to the development of giant telescopes"*

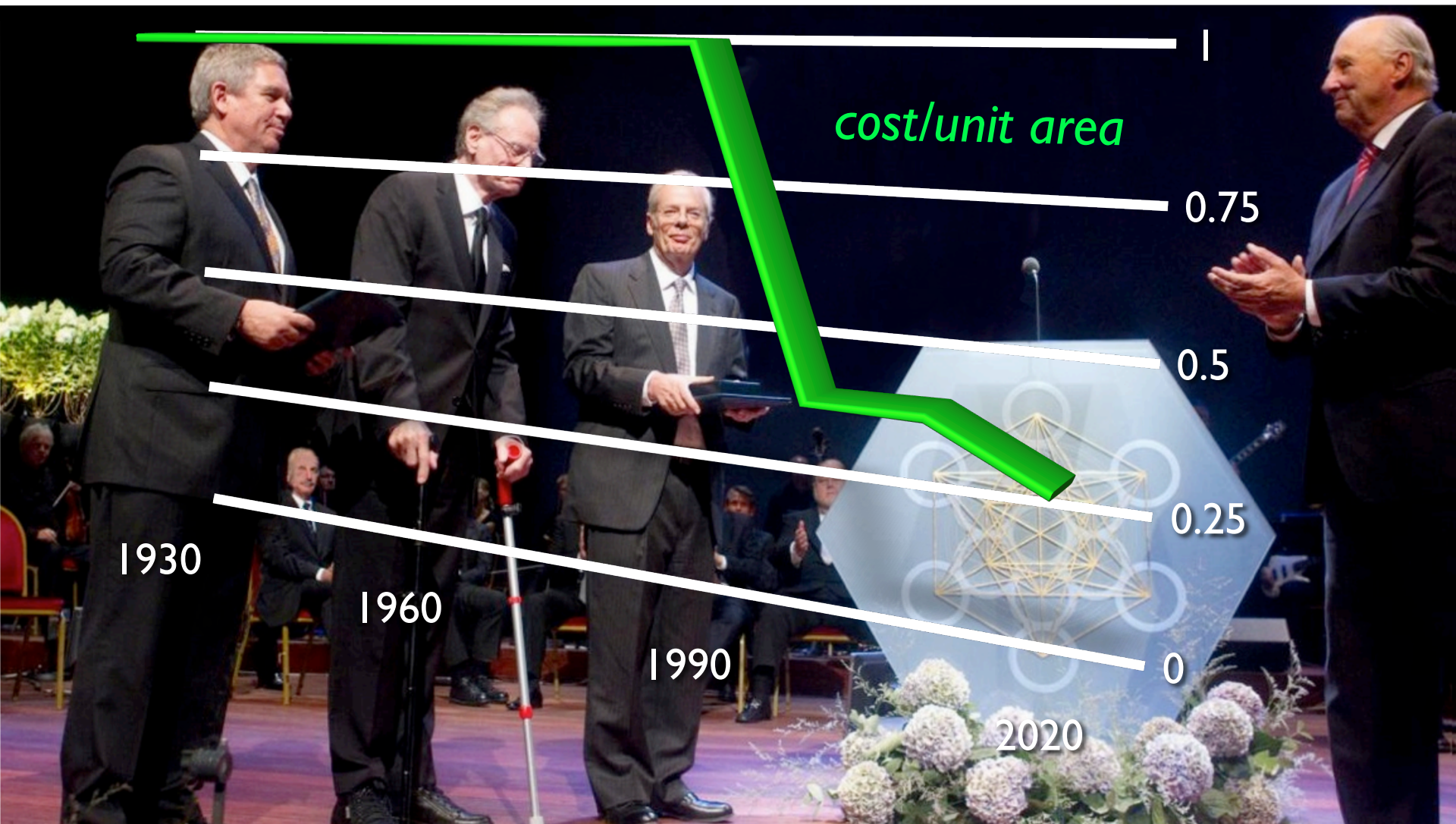


Jerry Nelson

Ray Wilson

Roger Angel

*“for their contributions to the development of giant telescopes”*

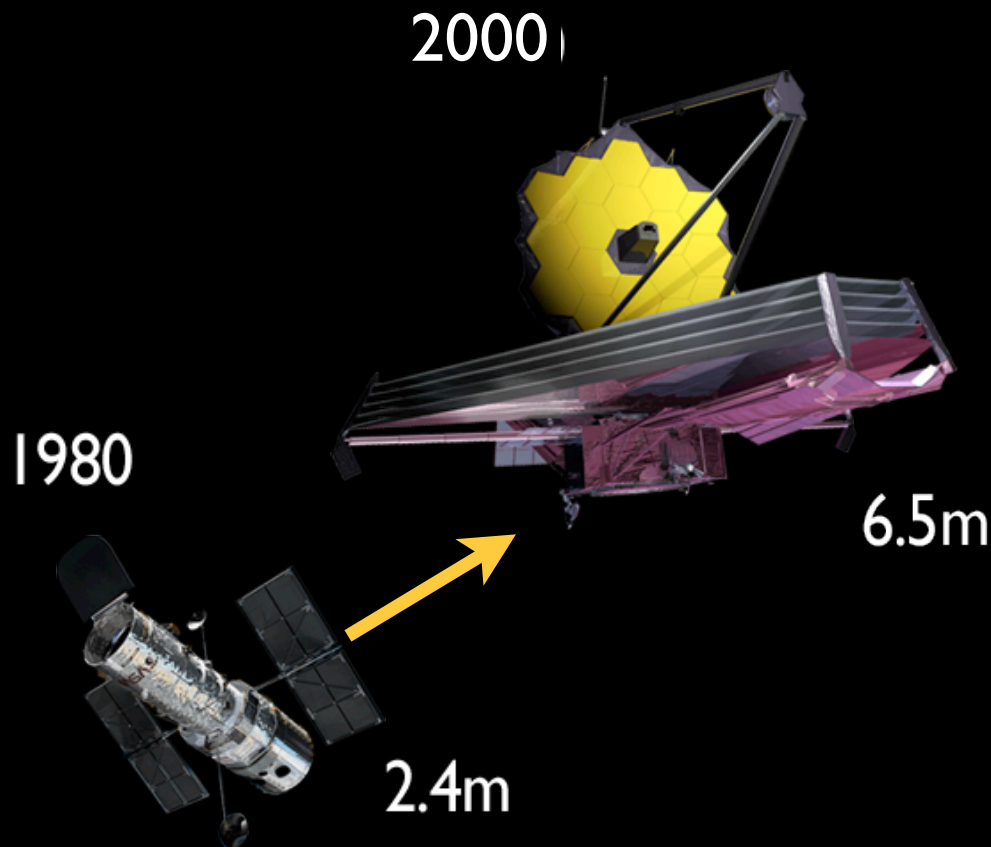


Jerry Nelson

Ray Wilson

Roger Angel

# Science challenges engineering and drives innovation

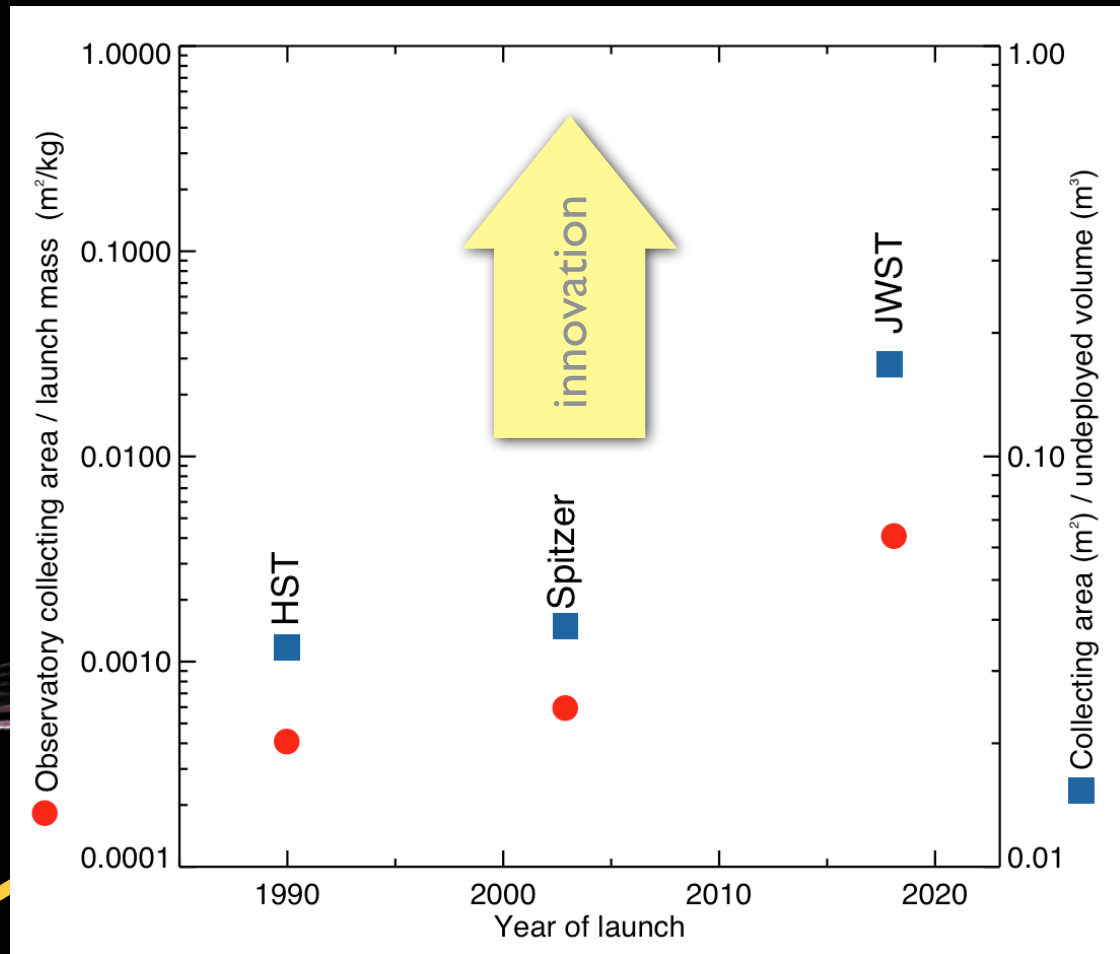


# Science challenges engineering and drives innovation

1980

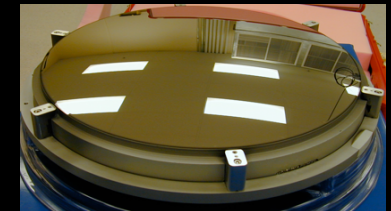
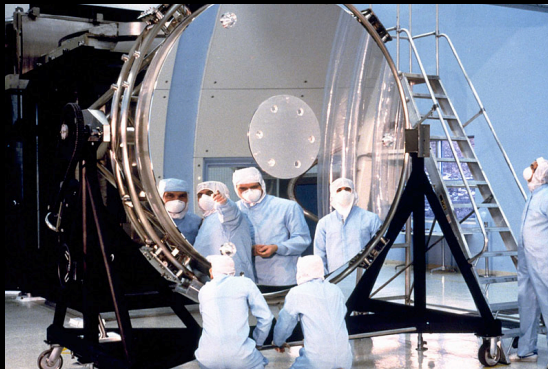


2.4m



courtesy E. Elliot *et al*

# Technology and innovative engineering *enable* science

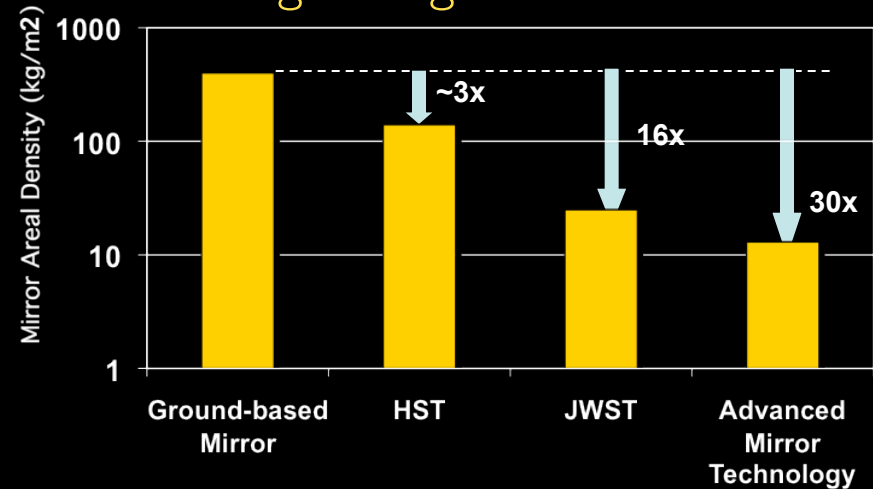


AMT Prototypes

# Technology and innovative engineering *enable* science

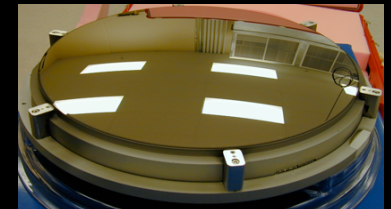


## Lightweight Mirrors



How much would an 8-m mirror weigh?

Gemini	HST	JWST	AMT
20,000 kg	7,000 kg	1,250 kg	650 kg

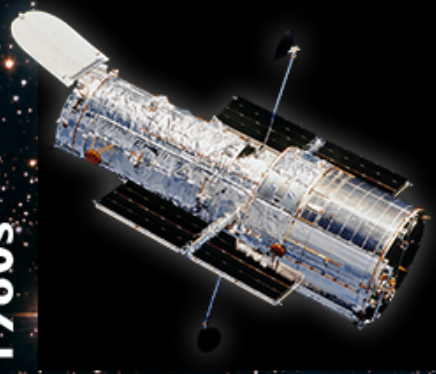


AMT Prototypes

1940s



1980s



1980s



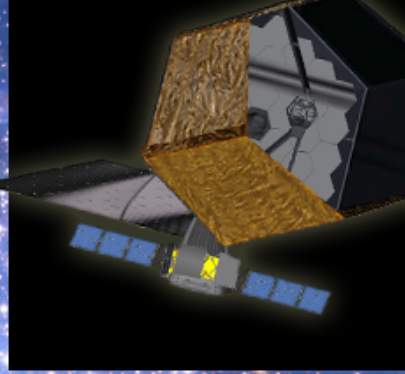
2010s



Present



Future



ESO/H.H.Heyer

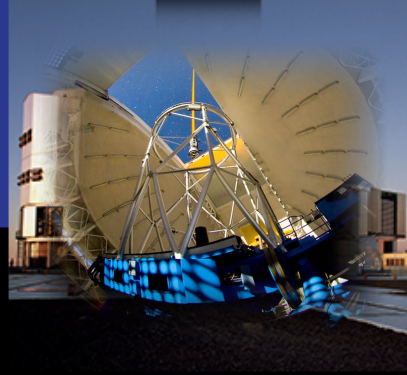
1940s



1980s



Present



ESO/H.I. Heyer

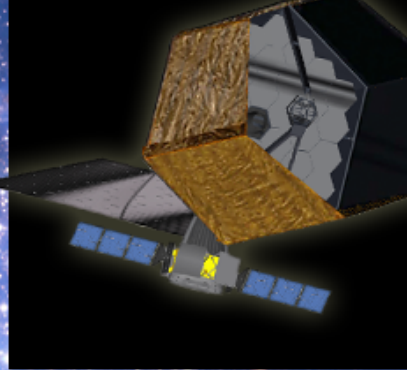
1980s

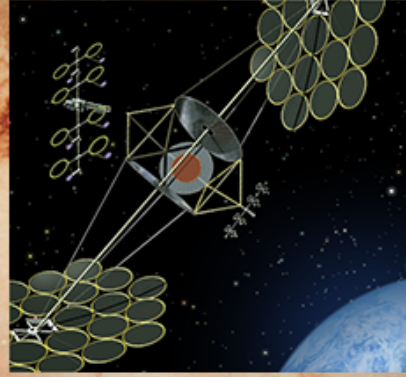


2010s



Future





**Security**



Google Maps

**Energy**



**Discovery**

**Are  
we  
alone?**



An artist concept of a lightweight space telescope that deploys a lens made from flexible membrane.  
Credit: DARPA

DARPA eventually wants a space telescope with a collection aperture (light-collecting power) of almost 66 feet (20 meters) in diameter. By comparison, NASA's next-generation James Webb Space Telescope is designed to have an aperture of just 21 feet (6.5 m).

# NASA's exploration infrastructure **has and will** continue to enable Space Science

Past and Present:



Astro-1 and 2

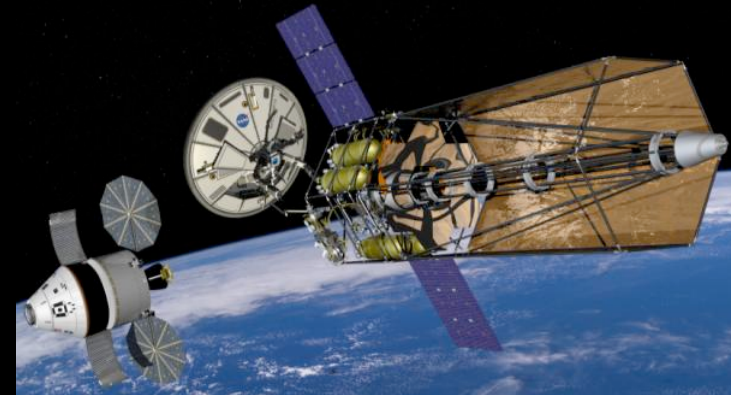


HST

Future:

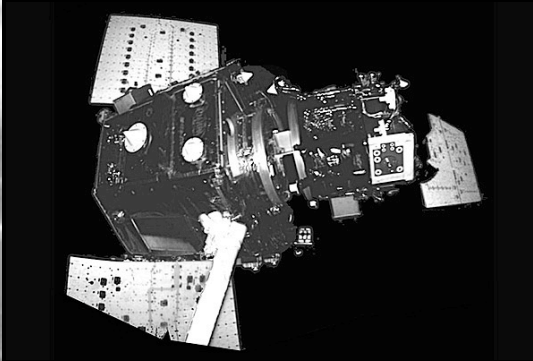


Heavy Launch Vehicles: Very Large UVOIR telescope)

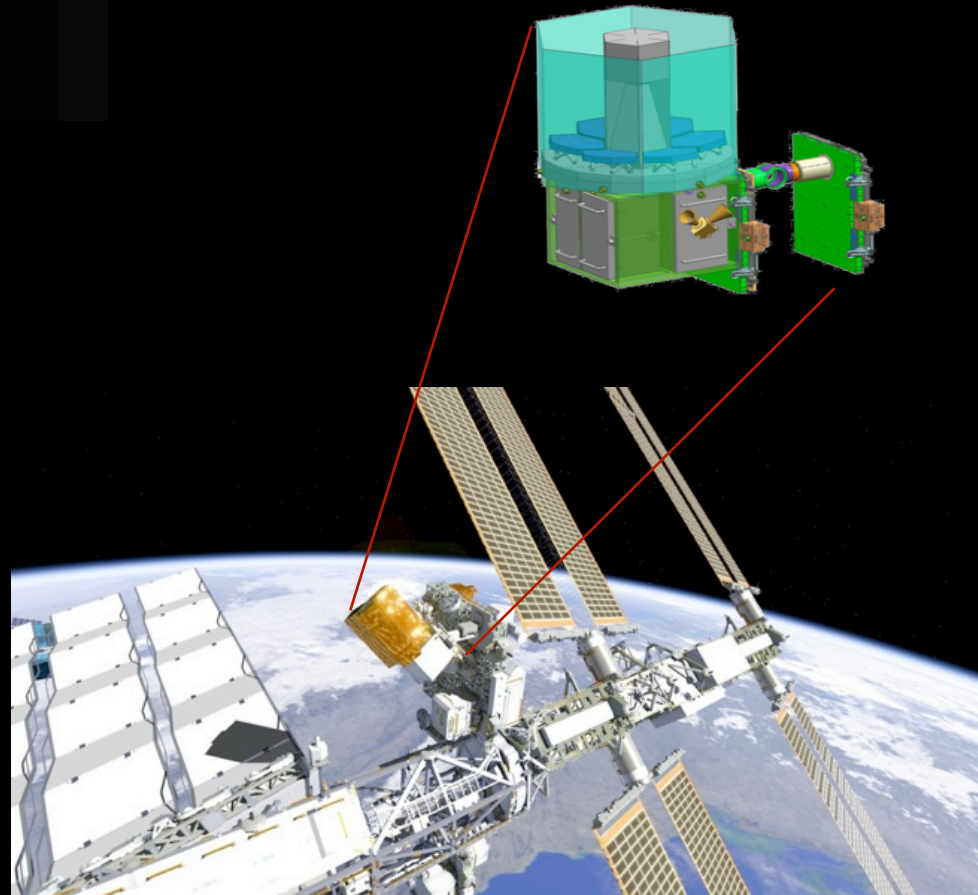


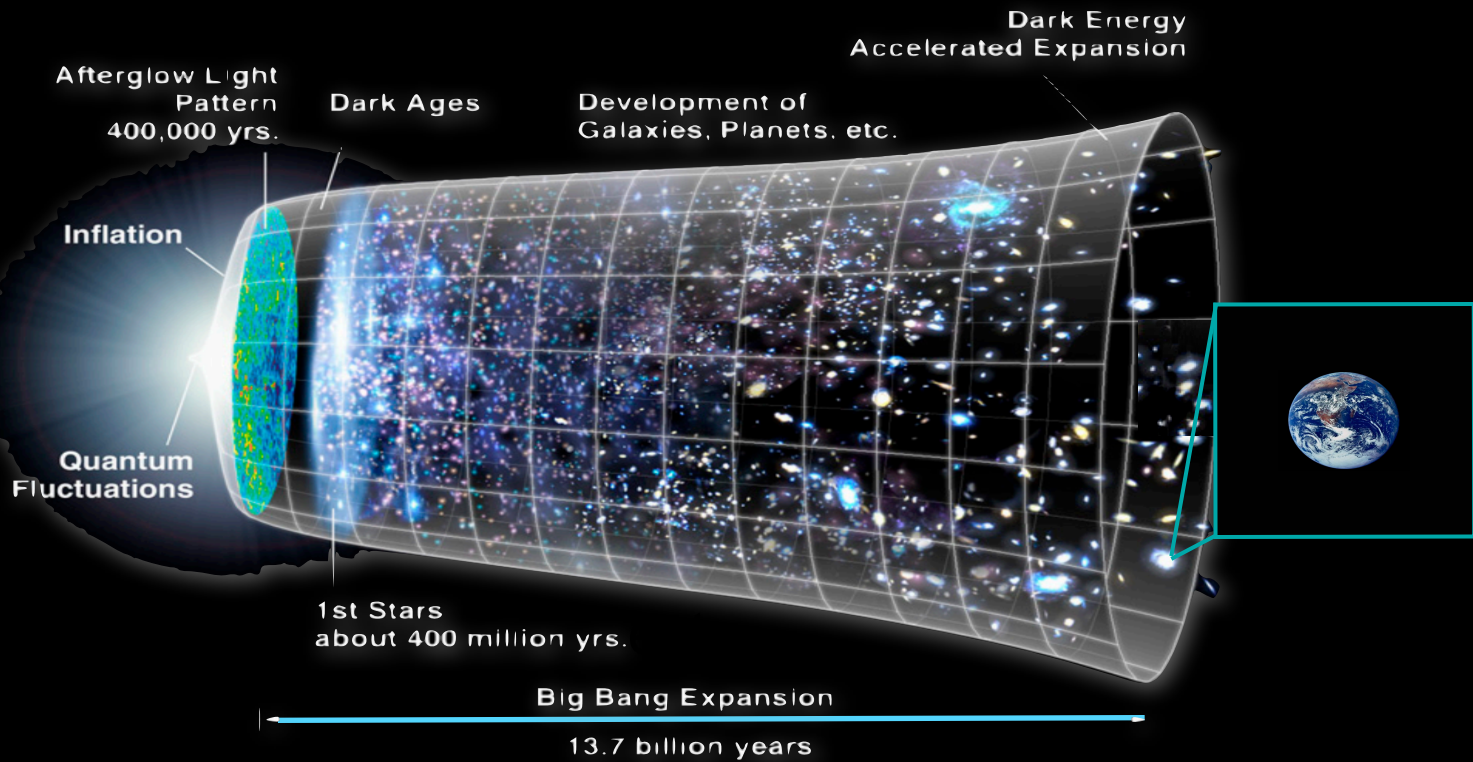
Tele-robotic observatory assembly and servicing in LEO or EM-LI

ISS is a potential test-bed  
for some of these key  
technologies

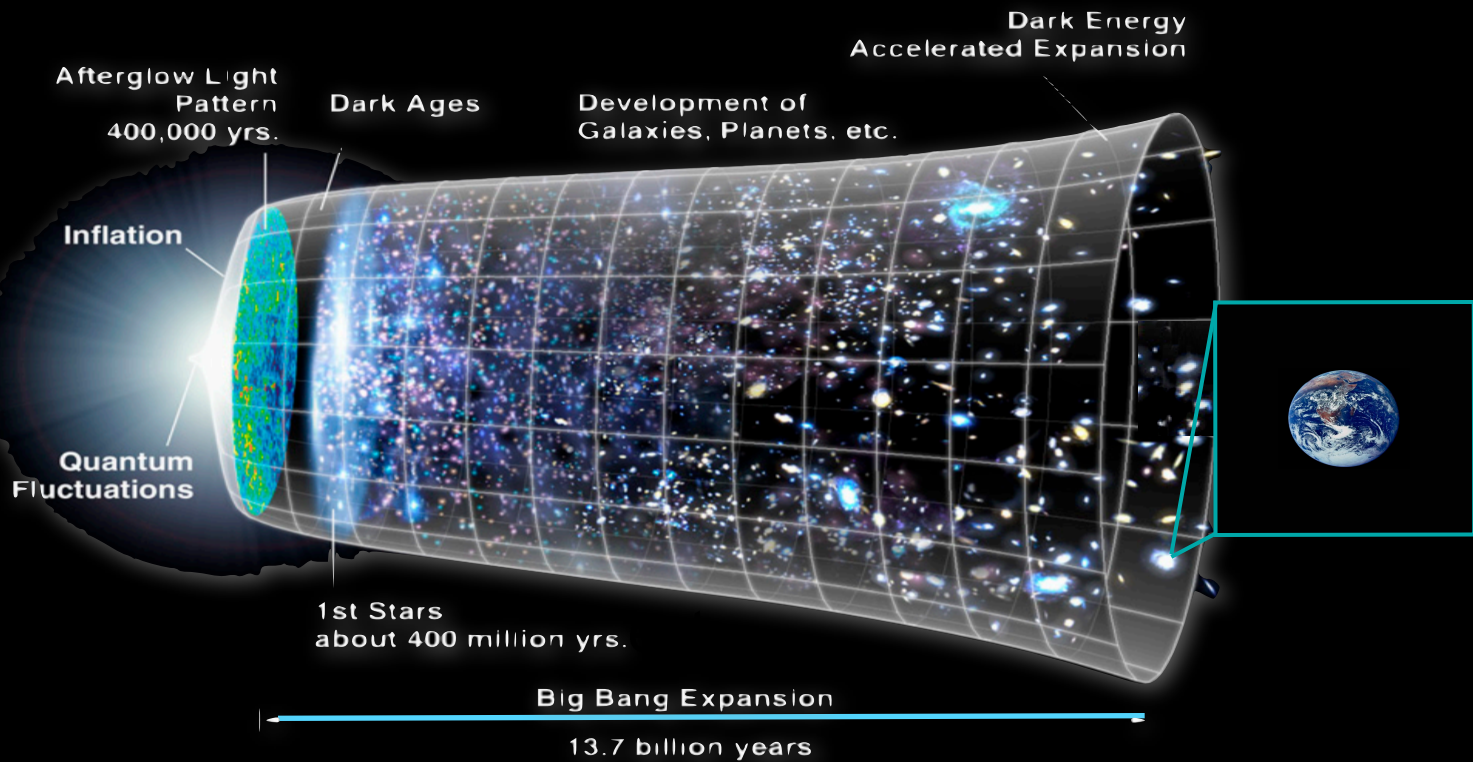


Orbital Express DARPA/TTO





We have a great story so far



We have a great story so far

Part II - for the first time in the history of our species we have the possibility to causally relate the conditions during the Big Bang to the emergence of RNA and DNA and the possibility to determine are we alone?

**THESE POSSIBILITIES CAN ONLY BE ENABLED BY NASA**

# OUR MISSION, SHOULD WE CHOOSE TO ACCEPT IT

*"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."*

Robert H. Goddard



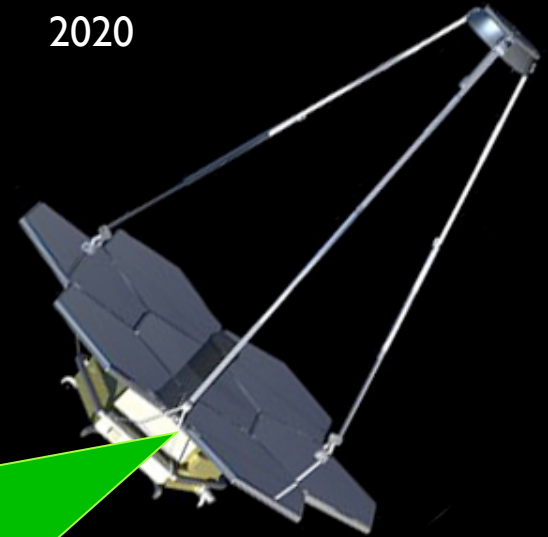
1980

2.4m \$1 <sup>great</sup>observatory (FY12)  
quantum



2000

6.5m \$1 <sup>great</sup>observatory (FY12)  
quantum



2020

8m~16m \$1 <sup>great</sup>observatory (FY12)  
quantum